Optical integration of incisoproximal restorations using the natural layering concept

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Objective: To evaluate the optical integration of 4 contemporary composite resin materials used for incisoproximal restorations and the natural layering concept. **Method and Materials:** Miris 2 (M2; Coltene Whaledent), Gradia Direct (GD; GC), Enamel Plus HFO (HFO; Micerium), and Filtek Supreme Plus (FSP; 3M ESPE) composite resins were used to consecutively restore 6 extracted incisors with incisoproximal restorations using the natural layering concept, mimicking the natural anatomy of the tooth with only 2 composite resin masses (dentin and enamel). Following each restoration, the specimen was allowed to rehydrate for 2 weeks and was then photographed under standardized conditions (direct, indirect, and fluorescent lights). Six independent evaluators scored each light condition using an optical integration score on a scale from 1 to 4 (1 = worst optical integration, restoration can be easily distinguished from remaining tissues; 4 = optimal optical integration, restoration "invisible"). Mean optical integration scores (from the 6 evaluators) were analyzed with a 2-way analysis of variance (ANOVA) (composite resin brand and light condition). Pooled data of M2 and HFO (single-hue systems) and GD and FSP (multiple-hue systems) were also analyzed with a 2-way ANOVA (shade system and light condition). **Results:** M2 obtained the highest optical integration scores ($P < .03$), followed by GD and HFO (not significantly different, $P = .99$). FSP showed the least favorable optical behavior ($P < .0001$), which is explained in part by the lack of fluorescence and possible inappropriateness for use with the natural layering technique. Single-hue systems (M2 and HFO) achieved better optical integration ($P < .02$) compared to multihue systems (GD and FSP). **Conclusions:** For M2, the simplified natural layering concept produced incisoproximal restorations with excellent optical integration. GD and HFO are also suitable for this technique. FSP failed to produce acceptable optical integration in the present study.
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Key words: composite resin, dental esthetics, natural layering technique, optical integration

Conservative esthetic restoration of anterior teeth using direct bonding represents a common treatment. Class IV defects provide a major challenge for the practitioner. To make the restoration imperceptible to the eye, the underlying fracture line must be carefully disguised through the subtle combination of restorative resins of different shades and opacities. A lot has been accomplished since the works of Bowen[1] and Buonocore.[2] The physicochemical and esthetic properties of composite resins have been significantly improved. Recent hybrid-type light-cured composites allow direct anterior restorations to be delivered with a better predictability of success and startling illusions.[3–14] The major esthetic improvements are based on the development of masses with different opacities and better matching with the optical properties of intact tooth substance.

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Fig 1 Patient with endodontically treated, discolored maxillary central incisors and Class IV defects on the maxillary right central incisor and left lateral incisor *(a)*. Both central incisors were first bleached using the walking bleaching technique. A palatal silicone matrix of the existing situation was used as a guide for the restoration with the natural layering concept *(b)*. Final optical integration following hard tissue rehydration *(c, d)*.

Another significant advance for the restoration of Class IV defects is the use of more natural, or toothlike, layering techniques also called "anatomic buildup technique,"[6] "trendy 3-layer concept,"[9] or "natural layering concept."[12] Inspired from the realm of dental porcelain, the goal of these methods is to mimic the natural anatomy of enamel and dentin. Only 2 basic composite masses (dentin and enamel) are used to optically mimic natural tissues. The procedure is facilitated by the use of a silicone matrix of the original tooth form. This stent can be obtained from previous dental casts of the patient, an existing restoration with appropriate shape but not appropriate shade (Fig 1), or from a waxup/mockup of the fractured tooth (Fig 2). The silicone matrix allows the precise placement and polymerization of an enamel-like shell of restorative material on the lingual or palatal aspect, which will in turn give support and guidance while developing the natural shape of dentin and facial-incisal enamel shell.

Most contemporary composite resins can be used with the natural layering concept, but little is known about the influence of the variations in the shading systems (single hue versus multiple hues), opacities, and fluorescence of these materials.

The aim of this study was to evaluate the optical integration of 4 contemporary composite resins recommended for Class IV defects. Emphasis was given to a standardized, simple, and clinically relevant evaluation method that would take into account various lighting conditions (direct and indirect lighting, fluorescence) and allow direct comparison with remaining intact enamel/dentin. The null hypothesis was that there was no difference among the 4 contemporary composite resins with regard to optical properties and comparison to intact tooth substrate.

Fig 2 Patient with a distoincisal defect on the maxillary right central incisor. The existing restoration is too short and nonfunctional *(a)*. The palatal silicone guide was fabricated on a study model after optimizing the shape and function of the incisor with a waxup *(b)*. The silicone matrix allowed accurate placement and polymerization of the initial palatal increment of enamel material *(b to e)*. This incisal "plate" is the perfect substrate for the application and shaping of the dentin increment *(f)*, the polymerization of which was followed by the closing of this "sandwich" with the facial enamel increment *(g)*. Final optical integration following hard tissue rehydration *(h to j)*.

METHOD AND MATERIALS

Six freshly extracted, sound human maxillary incisors stored in solution saturated with thymol were used. Approval was obtained from the University of Southern California Institutional Review Board. The color of each specimen was measured using an intraoral spectrophotometer (Vita Easy Shade, Vident) and double-checked visually by the operator using the Vita Classic shade guide (Vita). The measuring tip was positioned according to the manufacturer's indications. Both the incisal edge and the mid-third of the crown were measured using the "tooth areas" operating mode. The closest available shade of each composite resin brand was selected. For the single-hue systems not based on Vita shades, conversion charts provided by the manufacturer were used. Material shade selection is summarized in Table 1.

Table 1 Material shade selection for each specimen

	Specimen 1		2		3		4		5		6	
	D	E	D	E	D	E	D	E	D	E	D	E
Easy Shade measurement	A3.5	EN3	B4	EN1	B2	EN1	B3	EN2	B3	EN1	B4	EN2
Composite resin system												
Miris 2 (M2)	S3	IR	S4	WR	S2	WR	S3	NR	S3	WR	S4	NR
Gradia Direct (GD)	A3.5	CT	A4	WT	B2	WT	B3	NT	B3	WT	A4	NT
Enamel Plus HFO (HFO)	UD3.5	GE1	UD4	GE3	UD2	GE3	UD3	GE2	UD3	GE3	UD4	GE2
Filtek Supreme Plus (FSP)	A3D	YT	B3D	GT	A2D	GT	B3D	GT	B3D	GT	B3D	GT

(D) dentin, (E) enamel.

A palatal silicone guide was made (Platinum 85, Zhermack) for each specimen. A Class IV defect was then simulated by removing enamel and dentin from the mesial edge of each tooth. A flat-fractured surface was obtained by removing two-thirds of the mesial clinical crown height while maintaining one-third of the width of the incisal edge (distal part). A 1.0- to 1.5-mm bevel was prepared on the facial enamel.

The 6 specimens were restored according to the natural layering technique illustrated in Figs 1 and 2. First, a thin layer (about 0.5 to 1.0 mm) of enamel shade was placed into the silicone guide. This initial palatal increment was polymerized and the silicone index removed, followed by the application and shaping of the dentin increment (to simulate the original dentin shape). Polymerization of the dentin layer was followed by the closing of this "sandwich" with the facial enamel increment (about 0.5 to 1.0 mm). When necessary, excess composite resin was removed with an abrasive disk (Sof-Lex Pop-On XT No. 2381C, 3M ESPE).

Surface finishing was obtained by brushing on a thin layer of clear, low-viscosity glazing resin (Biscover LV, Bisco). All 6 specimens were restored with the same brand of composite resin and stored in distilled water at room temperature for 2 weeks to allow enamel/dentin rehydration. Following this delay, each tooth was photographed under standardized light conditions (Fig 3).

Because no bonding procedures were originally used, the restorations were easily removed without loss of remaining hard tissues. The 6 specimens were restored again with another composite resin brand (using the same procedures described above) and allowed to rehydrate for 2 weeks before being photographed again. The procedure was repeated for the third and fourth brands of composite resin.

The 4 materials tested consisted of 2 single-hue shade systems (Miris 2 [M2], Coltene Whaledent; and Enamel Plus HFO [HFO], Micerium) and 2 multiple-hue shade systems (Gradia Direct [GD], GC; and Filtek Supreme Plus [FSP], 3M ESPE). All procedures were performed by a single operator with equal experience in all 4 product brands.

The photographs were taken under standardized conditions with a digital camera (Fuji FinePix S2 Pro, Fujifilm), a 105-mm macro photography lens (Micro Nikkor AF105mm with Close Up No. 4T, Nikon), and a twin flash (Macro Speedlight SB21, Nikon) at magnification 1.5×. The camera sensor was positioned parallel to the long axis of the tooth. Precise framing was assisted by a grid in the camera viewfinder. Five photographs were taken under 3 light conditions (see Fig 3):

1. Direct light with the flash mounted on the lens (take 1) or positioned at a 45-degree angle (same distance from the specimen as in take 1) (take 2).
2. Indirect light with the flash positioned 1 inch behind the tooth (take 3) or 3 inches behind the tooth (take 4).
3. Direct fluorescent light (UV-Analysenlampe, Leuchtturm) (take 5).

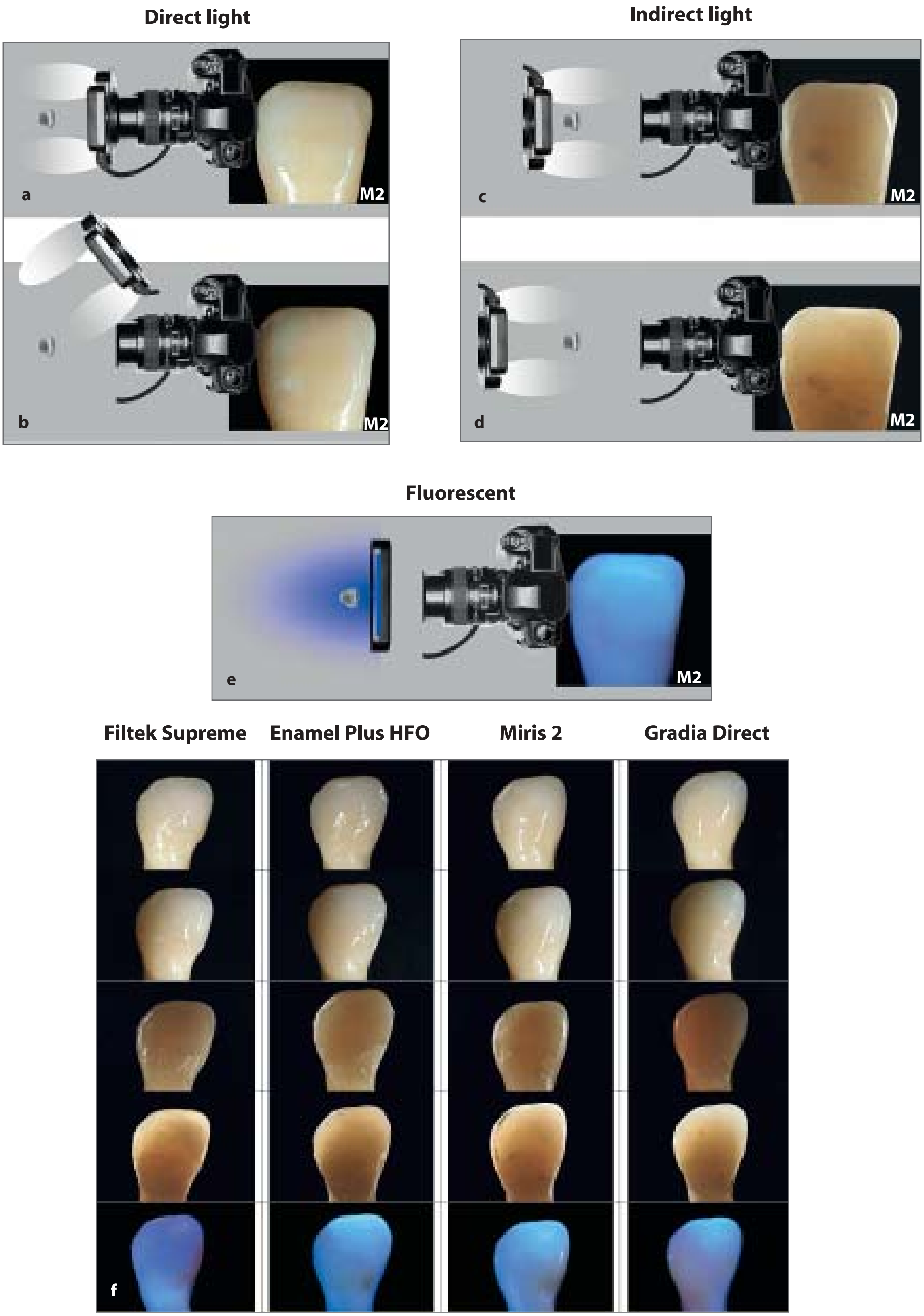

Fig 3 Standardized conditions for photography under direct *(a and b)*, indirect *(c and d)*, and fluorescent lights *(e)*. Photographs of the same specimen were arranged in a table *(f)*.

Table 2 Two-way ANOVA for composite resin system and light condition

Source	*df*	Type III sum of squares	Mean square	F	*P**
Composite resin brand	3	25.39	8.46	21.96	.000
Light condition	2	0.59	0.29	0.76	.47
Brand × light condition	6	9.16	1.53	3.96	.002

*$P < .05$ indicates statistically significant difference.

Table 3 Two-way ANOVA for shade system and light condition

Source	*df*	Type III sum of squares	Mean square	F	*P**
Shade system	1	13.35	13.35	20.20	.000
Light condition	2	0.59	0.29	0.44	.64
Shade system × light condition	2	0.72	0.36	0.54	.58

*$P < .05$ indicates statistically significant difference.

Table 4 Mean (SD) shade matching score of each composite resin brand tested

Composite resin system	Direct light	Indirect light	Fluorescent light
Miris 2 (M2)	3.48^{Aa} (0.32)	3.10^{Aa} (0.48)	3.70^{Aa} (0.33)
Gradia Direct (GD)	2.22^{Ba} (1.11)	2.98^{Aab} (1.03)	3.08^{ABb} (0.65)
Enamel Plus HFO (HFO)	3.25^{Aa} (0.41)	2.95^{Aab} (0.62)	2.28^{Bb} (0.63)
Filtek Supreme Plus (FSP)	2.27^{Ba} (0.46)	1.78^{Bab} (0.38)	1.27^{b} (0.41)

Values of groups having similar letters were not significantly different for $P < .05$ (uppercase letters refer to columns; lowercase letters refer to rows).

Table 5 Mean (SD) shade matching score of each shade system tested

Shade system	Direct light	Indirect light	Fluorescent light
Single-hue systems (M2/HFO)	3.37^{Aa} (0.37)	3.03^{Aa} (0.53)	2.99^{Aa} (0.88)
Multiple-hue systems (GD/FSP)	2.24^{Ba} (0.81)	2.38^{Aa} (0.97)	2.17^{Ba} (1.08)

Values of groups having similar letters were not significantly different for $P < .05$ (uppercase letters refer to columns; lowercase letters refer to rows).

All photographs of the same specimen were arranged as illustrated in Fig 3d. The 6 tables (1 per specimen) were presented to the evaluators without brand name (number codes were used) and with materials presented in random order. Six evaluators participated in the study (2 dental technicians, 2 clinicians, and 2 dental students). The optical integration score (OIS) was defined as the "visibility" of the restoration in comparison to remaining hard tissues on a scale from 1 to 4 (1 = worst optical integration, restoration can be easily distinguished from remaining tissues; 4 = optimal optical integration, restoration "invisible"). One OIS was attributed for each of the 3 light conditions (direct, indirect, fluorescence). Evaluators were allowed to grade with 0.5 decimals (eg, 1.5, 2.5, or 3.5), and no time limitation was set.

Mean OISs (from the 6 evaluators) were analyzed with a 2-way analysis of variance (ANOVA) (composite resin brand and light

Fig 4 Preoperative view of specimen *(a)* and corresponding views of Gradia Direct incisoproximal restoration in direct light *(b)* and in fluorescence *(c)*.

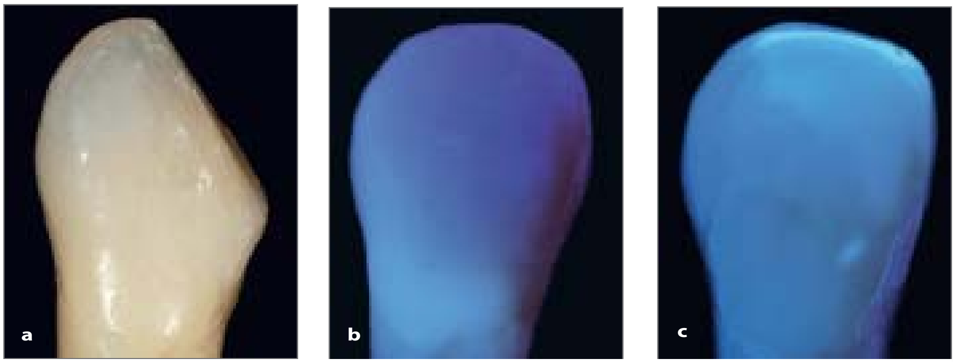

Fig 5 Preoperative view of specimen *(a)* and corresponding views of Filtek Supreme Plus *(b)* and Enamel Plus HFO (c) incisoproximal restorations in fluorescence.

condition). The Tukey Honestly Significance Difference (HSD) post hoc test was used to detect pairwise differences among experimental groups. All statistical testing was performed at a preset alpha of .05. Additional computations were obtained by pooling the data of M2/HFO (single-hue systems) and GD/FSP (multiple-hue systems). Mean OISs of pooled data were analyzed with a 2-way analysis of variance (ANOVA) (shade system and light condition) and the Tukey HSD post hoc test.

RESULTS

The 2-way ANOVA (Table 2) indicated a significant effect for the composite resin brand ($P < .001$) and the interaction term ($P = .002$) but not for the light condition ($P = .47$). The additional computations on pooled data for single-hue and multiple-hue composite resin brands (Table 3) revealed a significant effect of the shade system ($P < .001$). Table 4 lists the mean OIS for each of the 4 composite resin brands under the different light conditions. Table 5 lists the mean OIS of the 2 shade systems under the different light conditions. Under all light conditions combined (direct, indirect, and fluorescent), M2 (Figs 3a to 3e) performed better than all other products ($P < .03$), GD and HFO had similar OIS ($P = .99$), and FSP showed the least favorable optical behavior ($P < .0001$).

M2 performed identically under the different light conditions, while Gradia displayed a higher OIS in fluorescence compared to direct light (Fig 4). Inversely, HFO and FSP performed better in direct light compared to fluorescence. FSP was insufficiently fluorescent, while HFO displayed a larger amount of fluorescence compared to natural tissues (Fig 5).

Fig 6 Views of Miris 2 *(a)* and Enamel Plus HFO *(b)* incisoproximal restorations in direct light.

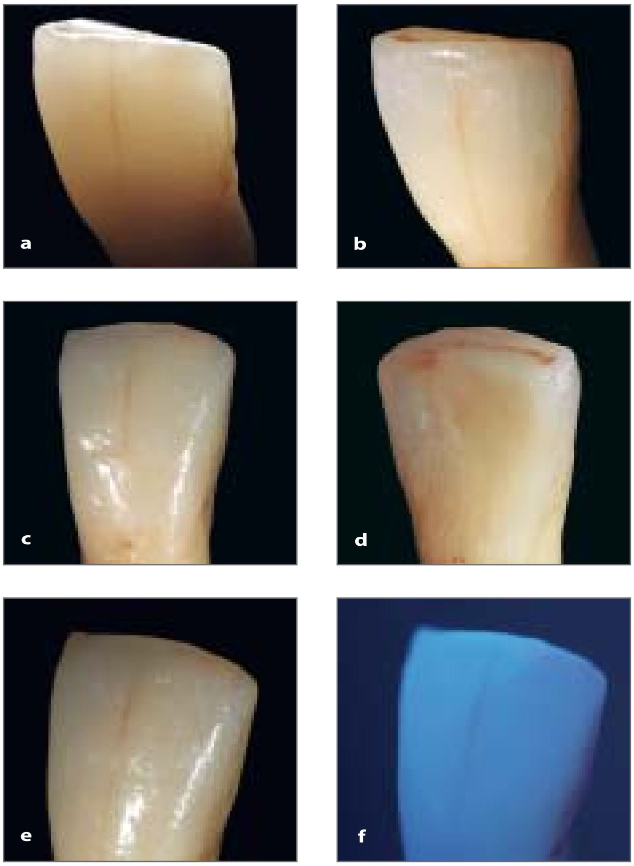

Fig 7 Example of Miris 2 mesial incisoproximal restoration under various light conditions. This restoration was fabricated using the natural layering concept during a demonstration in a training course for the university faculty.

Under direct light, M2 and HFO performed similarly (Fig 6) and had higher OISs than GD and FSP. Under indirect light, mean OISs for M2, GD, and HFO were not significantly different but were superior to FSP. Under fluorescent light FSP showed the least favorable results, while M2 and GD displayed the highest scores (GD was not significantly different from HFO).

Pooled data of single-hue systems and multiple-hue systems revealed that M2/HFO performed better in direct light (P = .001) and fluorescence (P = .017) than GD/FSP.

DISCUSSION

Color is often considered a major element of the esthetic success of a restoration. However, a minor error concerning that particular parameter might not be noticed if the other criteria, such as form, surface texture, and opacity, have been well-respected.[15] Of the 3 components of color,[16] luminosity (also called *value* or *brightness*) is most influential,[17,18] followed by chroma (also called *saturation* or *intensity* exhibited by a color) and hue (the color itself or name of the color). Hue might not be of critical importance because of the low concentration of hues in dental shades.

M2, the best overall material in this study, uses 2 basic composite resin masses (dentin and enamel) that optically mimic natural tissues.[12] This concept allows for simplified clinical application and layering, as it uses only 1 universal dentin hue with several chroma levels and 3 enamel types, each exhibiting specific translucency levels. Two of the systems in this study (GD and FSP) present several hues that could theoretically better match the spectrophotometer measurement; in view of the results, one can question the real need for these additional colors because multihue systems did not yield better OISs.

Color matching is as much a problem of color as a problem of opacity of the material.[19] A lack of opacity in the dentin shade can create a low value restoration, which is more likely to be noticed than a mistake in the hue. Interestingly, the material with the lowest OIS in indirect light (an indication of the material's opacity) also displayed the lowest score in fluorescence.

Fluorescence is another parameter that can influence the value of a restoration, because it makes teeth brighter and whiter in daylight.[20] It is defined as the ability to absorb radiant energy and emit it in the form of a different wavelength.[21] This present study confirms existing results about the lack of fluorescence of FSP.[22,23] Fluorescence is especially important for dentin substitutes. Dentin appears to be 3 times more fluorescent than enamel, which generates an internal luminescence. The latter is instrumental in the rendering of the vital appearance of a natural tooth, also called *vitalescence*. However, it is very difficult to faithfully reproduce the luminescence spectra (color and intensity) of enamel and dentin as demonstrated by in vitro spectral studies.[24,25] Composite materials show a wide range of fluorescence.[22,23,26] For the clinician, a simple but efficient way to approximately evaluate the fluorescence of a restoration in vivo is to check its optical interaction with a modified light source (black light blue).[27] Hybrid Fluorescent Opalescent (HFO) might have been the first product marketed with an emphasis on its fluorescence.[6] However, HFO systematically displayed a higher luminescence than enamel/dentin, while the more recent M2 and GD displayed appropriate fluorescence and were barely distinguishable from natural tissues under black light blue (Figs 3e, 4c, 7).

Optical integration of incisoproximal restorations is also influenced by the layering technique. The color of layered esthetic restorative materials is determined by the combination of all of the optical properties of constituent layers.[28] In view of the variations in the aforementioned elements (value, opacity, fluorescence, etc), the optical interaction can become very complex. While the effects of optical properties of the enamel layer seems to be more influential than those of the dentin layer, other optical properties of the latter influence the layered color.[28] The present study revealed that a simplification in the application process (single-hue shade selection, natural layering technique) can still result in very good optical integration despite the complex light interaction. Cases presented in Figs 1 and 2 were treated using these simplified principles, and the restorations did not require any postoperative corrections.

The process used in this study represents a simple and clinically relevant evaluation method taking into account various lighting conditions and using remaining intact enamel/dentin as a control. The same process can be replicated by the practitioner using extracted teeth as a trial for evaluating a new material before using it in the patient's mouth (Fig 7).

While it is understood that optical integration of incisoproximal restorations is influenced by the optical properties of the restorative material and the layering technique, one must remember that they do not represent a substitute to the knowledge of anatomic variations and careful observation of the adjacent teeth to produce a direct composite restoration in harmony with the surrounding dentition.[8]

CONCLUSIONS

A standardized, simple, and clinically relevant evaluation method was used to evaluate the optical integration of 4 contemporary composite resin materials used for incisoproximal restorations and the natural layering technique. Various lighting conditions (direct, indirect, and fluorescence) and direct comparison with remaining intact enamel/dentin revealed significant differences between composite resin brands and shading systems. Miris 2 obtained the highest optical integration scores, followed by Gradia Direct and Enamel Plus HFO. Filtek Supreme Plus showed the least favorable optical behavior, which is explained in part by the lack of fluorescence and possible inappropriateness for use with the natural layering technique. Single-hue systems (Miris 2 and Enamel Plus HFO) achieved better optical integration than did multihue systems (Gradia Direct and Filtek Supreme Plus).

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